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FILING DATE.**

**APPLICATION NUMBER: 60/473,842**

**FILING DATE: May 28, 2003**

**RELATED PCT APPLICATION NUMBER: PCT/US04/09645**

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# PROVISIONAL APPLICATION COVER SHEET [37 CFR 1.53(c)]

This is a request for filing a PROVISIONAL APPLICATION under 35 U.S.C. §111(b) and 37 CFR 1.51(a)(2)

Date : May 28, 2003

Docket No. : 50333/FLC/R268

EXPRESS MAIL NO. EV 352374704 US

Mail to: Mail Stop PROVISIONAL PATENT APPLICATION

INVENTOR(S)/APPLICANT(S) (LAST NAME, FIRST NAME, MIDDLE INITIAL, RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY))

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Additional inventors are being named on separately numbered sheets attached hereto.

TITLE OF THE INVENTION (280 characters max)

TCP WINDOW CONGESTION CONTROL

APPLICANT(S) STATUS UNDER 37 CFR § 1.27

☒ Applicant(s) and any others associated with it/them under § 1.27(a) are a SMALL ENTITY

## ENCLOSED APPLICATION PARTS

14 Specification (number of pages)

6 Drawings (number of sheets)

Assignment

☒ Other (specify): Appendices A-D

## FEE AND METHOD OF PAYMENT

☒ A check for the filing fee of \$ 80.00 is enclosed.

The Commissioner is hereby authorized to charge any fees under 37 CFR 1.16 and 1.17 which may be required by this filing to Deposit Account No. 03-1728. Please show our docket number with any charge or credit to our Deposit Account. A copy of this letter is enclosed.

☐ No filing fee enclosed.

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☐ No ☒ Yes, the name of the U.S. Government agency and the Government contract number are: ANI-9983138

Please address all correspondence to **CHRISTIE, PARKER & HALE, LLP, P.O. Box 7068, Pasadena, CA 91109-7068, U.S.A.**

Respectfully submitted,

CHRISTIE, PARKER & HALE, LLP

By

Frank L. Cire

Reg. No. 42,419

626/795-9900

PROVISIONAL APPLICATION FILING ONLY

FLC/sd

SD PAS506708.1--5/28/03 8:11 AM

1 50333/FLC/R268

## TCP WINDOW CONGESTION CONTROL

5 STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

The U.S. Government has certain rights in this invention pursuant to grants ANI-9983138 awarded by the National Science Foundation.

10 BACKGROUND OF THE INVENTION

This invention pertains generally to data transmission protocols and more specifically to moderating transmission rates in the presence of congestion.

The Transmission Control Protocol (TCP) provides end-to-end, reliable, congestion controlled connections over the Internet. The congestion control method used originally in TCP Tahoe included two phases: slow-start and congestion avoidance. In TCP Reno, recovery from sporadic packet losses is enhanced by fast retransmission and fast recovery. SACK-based TCPs provide the sender with more complete information about which packets are lost. Another class of algorithms is referred to as "NewReno" which does not need SACK information and requires only modification on the sender side. Research shows that the majority of TCP implementations are NewReno. Therefore, TCP Westwood and its refinement variants were implemented with NewReno as a base.

Increasingly, TCP is called upon to provide reliable and efficient data transfer over a variety of link technologies including wired and wireless with increasing bandwidth capacity. The new ultra high speed wired/wireless environment is exceeding the range for which TCP was initially designed, tested and tuned. As a consequence, active research is in progress to extend the domain of effective TCP operability. The use of path conditions estimate for enhancing congestion control in TCP has been proposed, termed TCP Vegas. In TCP Vegas, the sender infers the network congestion level from observed changes in Round Trip Time



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(RTT). If RTT becomes large, the source will decrease its congestion window (cwnd), thus reducing its transmission rate. However, new arriving connections to a congestion in progress may not be able to get a fair share of the bottleneck bandwidth. In a packet pair scheme, a sender estimates the bottleneck backlog and adjusts its sending rate accordingly. However, the packet pair scheme explicitly assumes round-robin scheduling at the routers - a feature not available in many commercial routers. Several network and link-layer enhancements have also been proposed to improve TCP performance under various conditions (congestion loss, random loss, handoff, out of order delivery, etc.), such as random early detection, Explicit Congestion Notification (ECN), and Explicit Loss Notification (ELN).

TCP Westwood design adheres to the end-to-end transparency guidelines and requires only sender side modification. The key innovation of TCP Westwood is to use a bandwidth estimate directly to drive a congestion window (cwin) and a slow start threshold (ssthresh) settings. The current estimation method in TCP Westwood is based on Bandwidth Estimation (BE). This TCP Westwood BE strategy provides significant throughput gains, especially the large leaky pipes. However, under certain congestion circumstances, BE exceeds the fair share of a connection resulting in possible unfriendliness to TCP New Reno connections.

Therefore, a need exists for a cwin and ssthresh setting method for TCP Westwood that reduces a TCP Westwood process's tendency to exceed its fair share of a connection. Various aspects of the present invention meet such need.

#### FEATURES

In one aspect of the invention, ACKnowledgments (ACKs) are used to estimate a connection rate share. The estimate of connection rate share is then used to directly set congestion

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control parameters to provide highly efficient congestion control.

5 In another aspect of the invention, a rate sample is obtained when an ACK arrives using information in the ACK regarding the delivered bytes and the last two ACKs inter-arrival time. The he samples are then exponentially averaged to produce smoothed rate estimates using a filter with time varying  
10 coefficients.

In another aspect of the invention, two estimators are maintained by a transmission control process to set cwin and ssthresh. The transmission control process uses the estimators to identify the predominant cause of packet loss using a Loss  
15 Discrimination Algorithm (LDA). The LDA relies on a ratio of expected throughput to achieved throughput. If this ratio exceeds a threshold (a parameter of this method), the LDA declares the packet loss to be resulting from congestion and therefore chooses an estimate based on an interval of length T, which is another  
20 parameter of this method. If on the other hand, the ratio of expected to achieved throughput is below the threshold, the loss is assumed to be the result of an error, and the sample interval is taken to be the last ACK inter-arrival time. The samples are exponentially averaged and filtered to produce smoothed eligible  
25 rate estimates. Depending on the outcome of the LDA, the appropriate estimator is used to set cwin and ssthresh. Both estimators use information obtained from ACKs received at the sender. One estimator BE, as in standard TCP Westwood, considers each ACK pair separately to obtain a bandwidth sample, filters  
30 the samples into a low-pass filter and returns as a result the available bandwidth that the TCP connection is estimated to be getting from the network. The other estimator, herein termed Rate Estimator (RE), considers the amount of data acknowledged during the latest interval of time T as sampled, then feeds such samples  
35 into an appropriate low-pass filter to get the estimated rate,

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in this case tending to estimate the throughput that the TCP Westwood connection has recently experienced. This method of  
5 using two estimators is herein termed Combined Rate and Bandwidth estimation (CRB).

In another aspect of the invention, the CRB method uses the relationship between the current cwin value and the estimated pipe size, the latter indicated by the product of RE and a  
10 minimum RTT (RTTmin). When  $RE * RTTmin$  is significantly smaller than cwin, it is more likely that packet losses are due to congestion. This is because the connection is using a cwin value much higher than its share of pipe size, thus congestion is likely. In CRB, whenever a packet loss is indicated, the sender  
15 determines the predominant cause of loss as follows: when the ratio  $RE * RTTmin$  to cwin exceeds a threshold value  $\theta$ , the use of RE is indicated. Below  $\theta$ , BE is indicated.

In another aspect of the invention, a packet loss is indicated either by a reception of 3 duplicate ACKs (DUPACKs) or  
20 a coarse timeout. The CRB method sets ssthresh and cwin after a packet loss indicated by three DUPACKs. If cwin divided by  $RE * RTTmin$  divided by the TCP segment size is greater than  $\theta$ , then a congestion condition is indicated and ssthresh is set to  $RE * RTTmin$  divided by the TCP segment size. Otherwise, ssthresh  
25 is set to  $BE * RTTmin$  divided by the TCP segment size. After ssthresh is adjusted, then cwin is compared to ssthresh. If cwin is greater than ssthresh then cwin is set to ssthresh.

In another aspect of the invention, an adaptive method is used to estimate the rate a connection is eligible to use. The  
30 estimation is adapted to the perceived congestion level in such a way that the resulting estimate, herein called "Eligible Rate", provides both higher efficiency as in the method above, as well as friendliness to other traffic types sharing the network path. Under packet loss because of congestion, the resulting eligible  
35 rate estimate is conservative, and thus improves friendliness by

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accommodating other traffic types sharing the network resources.  
Under low congestion, a packet loss is assumed to be the result  
5 of random error. The resulting eligible rate estimate is more  
aggressive, improving efficiency under random loss.

In another aspect of the invention, herein termed Adaptive  
Bandwidth Share Estimation (ABSE), the sample interval T is  
continuously adapted to the perceived network congestion level.  
10 The sample interval can be as small as the latest ACK inter-  
arrival time, and can grow in a continuous manner up to the  
estimated minimum round trip time of the connection. The  
congestion level is determined from the difference between the  
expected throughput and the achieved throughput of the  
15 connection. The samples are exponentially averaged and filtered  
to produce the eligible rate estimate. The eligible rate estimate  
is then used to set cwin and ssthresh as before.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 These and other features, aspects, and advantages of the  
present invention will become better understood with regard to  
the following description, accompanying drawings, and attached  
appendices where:

FIG. 1 is an equation for a current rate estimator in  
25 accordance with an exemplary embodiment of the present invention;

FIG. 2 is an equation for a rate estimator for a previous  
rate estimator in accordance with an exemplary embodiment of the  
present invention;

FIG. 3 is an equation for a current rate estimator using a  
30 previous rate estimator in accordance with an exemplary  
embodiment of the present invention;

FIG. 4 is an equation for a filtered rate estimator in  
accordance with an exemplary embodiment of the present invention;

FIG. 5 is a pseudocode listing for a TCP control process in  
35 accordance with an exemplary embodiment of the present invention;



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FIG. 6 is a block diagram of a computing device suitable for hosting a transmission protocol control process in accordance with an exemplary embodiment of the present invention;

FIG. 7 is a pseudocode listing for a TCP control process using an adaptive bandwidth share estimate in accordance with an exemplary embodiment of the present invention;

Appendix A is a publication describing a first method of calculating a BE in accordance with an exemplary embodiment of the present invention;

Appendix B is a publication describing simulation results of an investigation of an exemplary embodiment of the present invention;

Appendix C is a publication describing an adaptive bandwidth share estimation process in accordance with an exemplary embodiment of the present invention; and

Appendix D is a publication describing a specific implementation of the present invention.

#### DETAILED DESCRIPTION

To identify the predominant cause of packet loss, ECN and ELN can be used. However, ECN requires all the routers along a network path to support ECN, while ELN has its share of implementation problems as reported in. Instead, a method to identify the predominant cause of packet loss may be used that does not require support from lower layers. The method uses the relationship between the current congestion window value and the estimated pipe size, the latter being defined as the product of RE and the minimum RTT observed. The pipe size corresponds to the ideal window required to achieve the rate RE. When the measured pipe size is significantly smaller than cwin, it is very likely that packet losses are due to congestion.

TCP design aims to utilize all available bandwidth, while maintaining "fairness" in the allocations made to different flows.



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5 Fairness is achieved by equally allocating the available  
bandwidth to active TCP flows, unless some of them are inherently  
unable to use their share regardless of the existence of  
competing flows. For instance, on a "leaky" large pipe, NewReno  
utilization is dramatically reduced. In this case, a flow using  
a new proposed protocol can achieve higher bandwidth share and  
preserve fairness. However, this should be accomplished without  
10 reduction in the legacy connections throughput. Fair bandwidth  
share may be defined for the following cases:

- a) for N TCP Westwood flows sharing a bottleneck link with  
capacity C, the fair share is  $C/N$ ;
- 15 b) for a total of N TCP Westwood and TCP NewReno flows,  
assuming that no random errors are possible, both protocols  
are roughly equivalent, and therefore the fair share for  
each flow is  $C/N$ ;
- 20 c) Assuming that there are random errors on the paths (e.g.  
from a wireless link) to which all flows are subjected.  
Because TCP NewReno flows are inherently unable to utilize  
the link capacity in this case, TCP Westwood flows should  
not be considered aggressive by getting a larger bandwidth  
share than the NewReno flows. We define the fair share of  
25 a NewReno flow as the same value if all flows are TCP  
NewReno. For instance, suppose the fair share of the NewReno  
flow is  $S_r$  given that there are total N homogenous TCP  
NewReno flows, then when this total N flows includes some  
TCP Westwood flows, the fair share of NewReno flow should  
remain  $S_r$ , while TCP Westwood flows could have a fair share  
30 of higher value. Thus, a TCP Westwood fair share can be  
higher than a NewReno share since the latter connection is  
inherently incapable of using the link capacity.
- 35 d) In the presence of non-adaptive high-priority flows (e.g,  
real time streaming traffic) which take away a portion of  
bandwidth determined by their transmission rates, we just

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5 reduce the capacity available to TCP connections by the  
amount used by the non-adaptive flows and proceed to  
calculate fair share of a TCP Westwood connection as in the  
above three cases.

10 In TCP Westwood, the BE estimator is used to drive cwnd and  
ssthresh determination. This protocol has been shown to achieve  
a high utilization when used over large leaky pipes. In certain  
cases, BE may overestimate its fair share. In this case, TCP  
NewReno (and other TCP-like protocols) may experience performance  
degradation. TCP Westwood Rate Estimation (RE) addresses the  
issue of friendliness to NewReno. Both estimations are based on  
15 the ACK arrival process received by the TCP-W sender; thus, they  
are passive and introduce no extra link overhead.

A TCP Westwood sender uses ACKs to estimate BE. More  
precisely, the sender uses the following information: (1) the ACK  
reception rate; and (2) the information an ACK conveys regarding  
20 the amount of data recently delivered to the destination. For  
details regarding the processing of ACKs in (2), please refer to  
APPENDIX A.

Significant efficiency improvements are obtained using the  
BE estimator produced by the sampling and filtering methods  
25 above. This is particularly true in environments with large leaky  
pipes. Further, note that when routers employ around robin policy  
in scheduling transmissions, BE is accurate in estimating a  
connection fair share. However, for drop-tail routers, since TCP  
traffic tends to be "bursty", i.e. sending out a full window of  
30 packets and then waiting for the acknowledgments, BE may  
over-estimate the connection fair share.

Consider an alternative bandwidth sample, defined as the  
amount of data reported to be delivered by all ACKs that arrived  
in the last T time units, divided by T. This method is herein  
35 termed Rate Estimation (RE). This alternative is identical to

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the earlier TCP Westwood sample definition if the ACKs are uniformly spaced in time. Simulation and measurements, however, show that ACKs tend to cluster in bursts. Thus, the BE sampling method "overestimates" the connection fair share, while providing (in the bursty case) a reasonably good estimate of the available bandwidth at the bottleneck. Thus, BE is more effective in environments with random error, and when single connection efficiency is paramount.

The RE sample associated with the  $k$ th received ACK is expressed by the equation in FIG. 1, where:  $d_j$  is the amount of data reported by ACK  $j$ . Similarly, at the previous time instant,  $k-1$ , the sample  $k-1$  is given by equation in FIG. 2. Therefore, the RE associated with the  $k$ th received ACK can be determined from the RE associated with the  $k-1$  received ACK as given in the equation in FIG. 3. Thus, at any instant, a sliding window of length  $T$  is used to obtain a bandwidth sample.

The expression above is a recursive one, because the sample is calculated using its previous value as reference. Additionally, the technique places equal emphasis on all data points in the sampling range. Thus a value in the near past will have the same influence as a more current measurement when calculating the sample. This is a desirable feature when we are dealing with bursty TCP traffic in presence of congestion. Finally, sliding window samples are exponentially averaged in order to obtain a smoothed bandwidth share estimate over time. A simple exponential averaging filter to calculate the Rate Estimate at the instant the  $k$ th ACK is received is given by the equation in FIG. 4.

BE is more effective than RE as an estimate in environments with random error. On the other hand, the RE method appears to be more appropriate when packet losses are because of congestion (router buffer overflow). Based on the tradeoff presented above, a hybrid method that combines both sampling strategies would be

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of interest, provided one can determine the cause of packet loss: errors or buffer overflow. This issue of course is beyond the  
5 sampling methodology investigation itself. In fact, if a sender were able to distinguish with certainty between error and buffer overflow losses, the sender reaction to the former would be to retransmit immediately with no change of window size.

The following method may be used to determine the  
10 predominant cause of packet loss requiring no assistance from layers below TCP. The method is herein termed Combined Rate and Bandwidth estimation (CRB). The CRB method uses the relationship between the current cwin value and the estimated pipe size, the latter indicated by the product of RE and the minimum RTT. When  
15  $RE * RTT_{min}$  is significantly smaller than cwin, it is more likely that packet losses are due to congestion. This is because the connection is using a cwin value much higher than its share of pipe size, thus congestion is likely. In CRB, whenever a packet loss is indicated, the sender determines the predominant cause  
20 of loss as follows: when the ratio  $RE * RTT_{min}$  to cwin exceeds a threshold value  $\theta$ , the use of RE is indicated. Below  $\theta$ , BE is indicated. A threshold of  $\theta=1.4$  was found to give the satisfactory results.

A packet loss is indicated either by a reception of 3  
25 DUPACKs or a coarse timeout. The CRB method sets ssthresh and cwin after a packet loss indicated by three duplicate ACKs. Referring now to FIG. 5, a pseudo-code listing is presented for the CRB method. In the pseudo-code, seg\_size identifies the length of a TCP segment in bits. The value  $RTT_{min}$  is set as the  
30 smallest RTT estimated by TCP, using its own RTT estimation method. Note that the basic Reno behavior is still captured, while setting ssthresh to the value of BE or RE, as appropriate, provides a more rational recovery.

In another aspect of the invention, the TCP sender  
35 Adaptively determines a Bandwidth Share Estimate (TCP-ABSE).



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As such, TCPW ABSE is then a sender-only modification of TCP NewReno. The estimate is based on information in the ACKs, and  
5 the rate at which the ACKs are received. After a packet loss indication, which could be due to either congestion or link errors, the sender uses the estimated bandwidth to properly set the congestion window and the slow start threshold.

FIG. 7 is a pseudocode listing for a TCP control process  
10 using an adaptive bandwidth share estimate in accordance with an exemplary embodiment of the present invention. In TCP-ABSE, a sender determines a connection bandwidth estimate as mentioned above and uses it to set cwin and ssthresh after a packet loss indication. The rationale of the algorithm above is that after  
15 a timeout, cwin and the ssthresh are set equal to 1 and ABSE, respectively. Thus, the basic Reno behavior is still captured, while a reasonably speedy recovery is ensured by setting ssthresh to the value of ABSE.

An Adaptive Bandwidth Share Estimation (ABSE) process adapts  
20 to the congestion level in performing its bandwidth sampling, and employs a filter that adapts to the round trip time and to the rate of change of network conditions. The bandwidth estimation is computed using a time varying coefficient, Exponentially-Weighted Moving Average (EWMA) filter, which has  
25 both adaptive gain and adaptive sampling.

FIG. 8 is a data flow diagram depicting an adaptive  
bandwidth share estimation process in accordance with an exemplary embodiment of the present invention. An ACK stream is received by the process and used to generate a recent throughput  
30 sample. The recent throughput is used in conjunction with an expected throughput to generate a sampling time interval. The time interval is then used in conjunction with the ACK stream to generate an unfiltered bandwidth share sample. The unfiltered bandwidth share sample is used to generate a network instability  
35 measure which is filter to generate a filter gain. The filter

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gain is used in conjunction with the unfiltered bandwidth share sample to generate a filtered adaptive bandwidth share estimate.  
5 The equations governing the functional blocks described above are given in Appendix C, the contents of which are hereby incorporated by reference as if stated fully herein. A specific implementation of the present invention is described in Appendix D, the contents of which are hereby incorporated by reference as  
10 if stated fully herein.

FIG. 6 is a block diagram of a computing device suitable for hosting a transmission protocol control process in accordance with an exemplary embodiment of the present invention. A host includes a processor coupled via a bus to a memory device, a  
15 storage device controller, and a network device controller. The processor uses the network device controller to control the operations of a network device which is adapted for communications using a transport protocol to transmit data to a receiver across a connection through a computer network.

20 The storage controller is coupled to a storage device having a computer readable storage medium for storage of program instructions executable by the processor. The program instructions are stored in the storage device until the processor retrieves the program instructions and stores them in the memory.  
25 The processor then executes the program instructions stored in memory to implement the transport protocol control process as previously described.

Although this invention has been described in certain specific embodiments, many additional modifications and  
30 variations would be apparent to those skilled in the art. It is therefore to be understood that this invention may be practiced otherwise than as specifically described. Thus, the present embodiments of the invention should be considered in all respects as illustrative and not restrictive, the scope of the invention

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to be determined by claims supported by this application and the  
claims' equivalents rather than the foregoing description.

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ABSTRACT OF THE DISCLOSURE

A refinement of TCP Westwood allowing the management of the Efficiency/Friendliness-to-NewReno tradeoff is provided. TCP Westwood implements a novel congestion window control method based on available bandwidth estimation. The original TCP Westwood sampling strategy that produces available Bandwidth Estimates (BE) is combined with a new strategy that produces Rate Estimates (RE). The new strategy is called Combined Rate and Bandwidth estimation (CRB). To use CRB, a connection first infers the predominant cause of packet losses, and then uses the most appropriate estimation method.

FLC/flc

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**PROVISIONAL APPLICATION COVER SHEET [37 CFR 1.53(c)]**

This is a request for filing a **PROVISIONAL APPLICATION** under 35 U.S.C. §111(b) and 37 CFR 1.51(a)(2)

Date : May 28, 2003

Docket No. : 50333/FLC/R268

**EXPRESS MAIL NO. EV 352374704 US**

**Mail to: Mail Stop PROVISIONAL PATENT APPLICATION**

**INVENTOR(S)/APPLICANT(S)** (LAST NAME, FIRST NAME, MIDDLE INITIAL, RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY))

Gerla, Mario, Santa Monica, California and Sanadidi, M. Yahya, Santa Monica, California

Additional inventors are being named on separately numbered sheets attached hereto.

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TCP WINDOW CONGESTION CONTROL

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☒ Applicant(s) and any others associated with it/them under § 1.27(a) are a **SMALL ENTITY**

**ENCLOSED APPLICATION PARTS**

☐ 14 Specification (number of pages)

☐ 6 Drawings (number of sheets)

☐ Assignment

☒ Other (specify): Appendices A-D

**FEE AND METHOD OF PAYMENT**

☒ A check for the filing fee of \$ 80.00 is enclosed.

The Commissioner is hereby authorized to charge any fees under 37 CFR 1.16 and 1.17 which may be required by this filing to Deposit Account No. 03-1728. Please show our docket number with any charge or credit to our Deposit Account. **A copy of this letter is enclosed.**

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☐ No ☒ Yes, the name of the U.S. Government agency and the Government contract number are: ANI-9983138

Please address all correspondence to **CHRISTIE, PARKER & HALE, LLP, P.O. Box 7068, Pasadena, CA 91109-7068, U.S.A.**

Respectfully submitted,

CHRISTIE, PARKER & HALE, LLP

By

Frank L. Cire

Reg. No. 42,419

626/795-9900

**PROVISIONAL APPLICATION FILING ONLY**

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$$RE_k = \frac{\sum_{t_j > t_k - T} d_j}{T}$$

FIG. 1

$$RE_{k-1} = \frac{\sum_{t_j > t_{k-1} - T} d_j}{T}$$

FIG. 2

$$RE_k = RE_{k-1} + \frac{d_k - \sum_{i: l_i \leq k-1, d_i > k-1-1} d_i}{T}$$

FIG. 3

$$\hat{RE}_k = \frac{19}{21} RE_{k-1} + \frac{1}{21} (RE_k + RE_{k-1})$$

FIG. 4

```
if (3 DUPACKs are received)
  if (cwin / ((RE * RTTmin) / seg_size) > 0) /* Congestion condition */
    ssthresh = (RE * RTTmin) / seg_size;
  else /* no congestion */
    ssthresh = (BE * RTTmin) / seg_size;
  endif
  if (cwin > ssthresh) /* congestion avoid. */
    cwin = ssthresh;
  endif
endif
```

FIG. 5



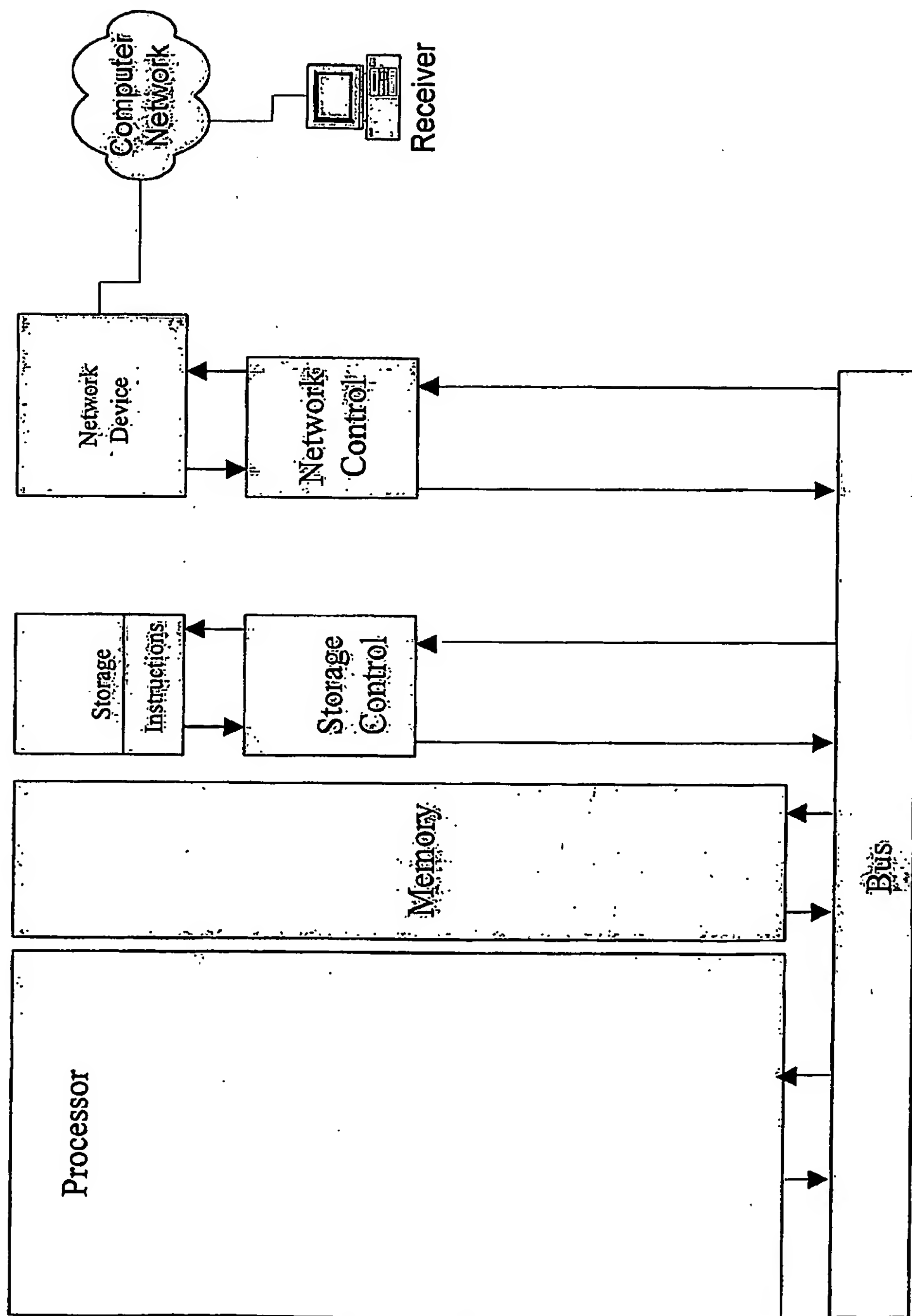


FIG. 6

```
if (3 DUPACKs are received)
    ssthresh = (ABSE * RTTmin) / seg_size;
    if (cwin > ssthresh) /* congestion avoid. */
        cwin = ssthresh;
    endif
endif
```

In case a packet loss is indicated by a timeout expiration, *cwin* and *ssthresh* are set as follows:

```
if (coarse timeout expires)
    cwin = 1;
    ssthresh = (ABSE * RTTmin) / seg_size;
    if (ssthresh < 2)
        ssthresh = 2;
    endif
endif
```

FIG. 7

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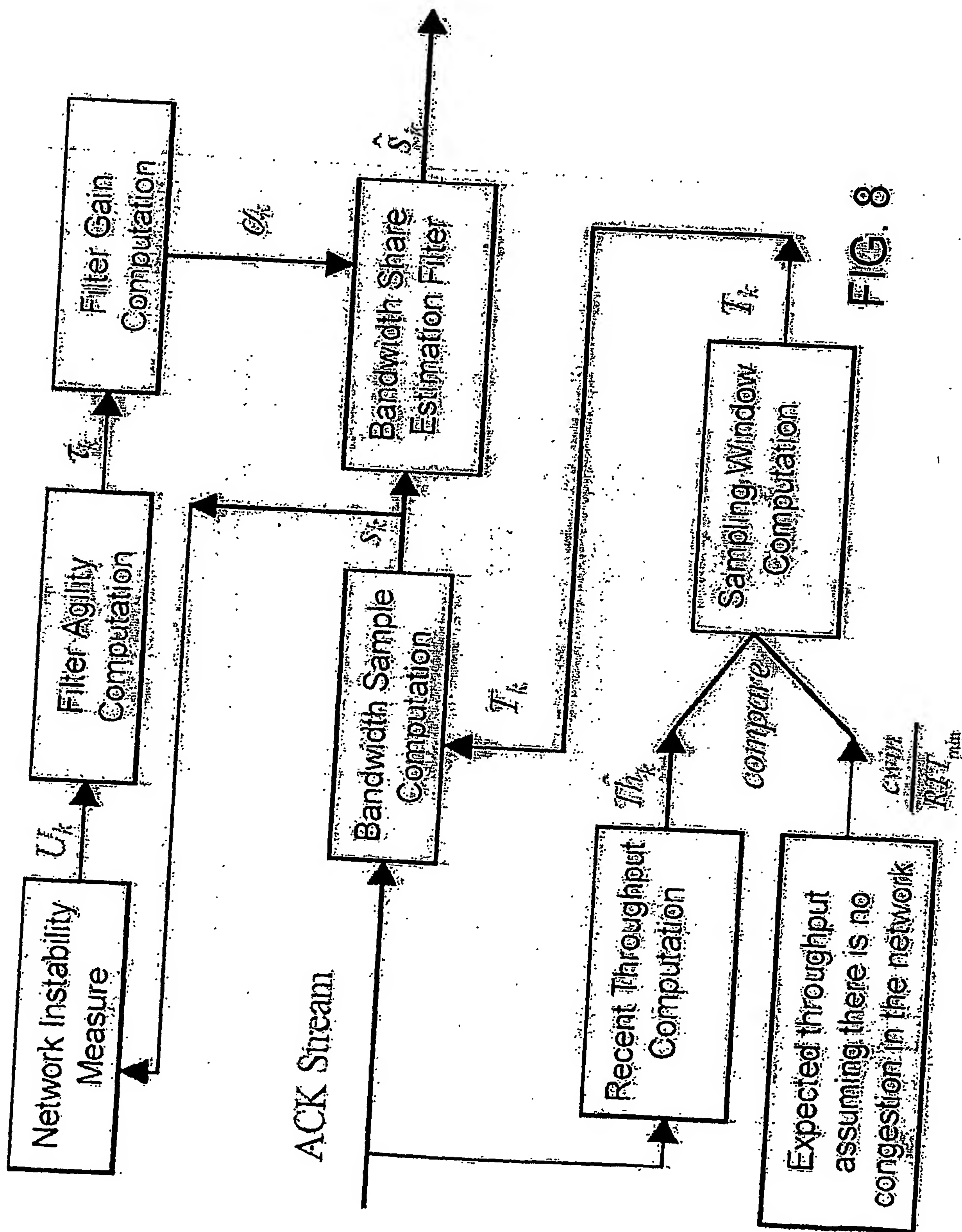


FIG. 8

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